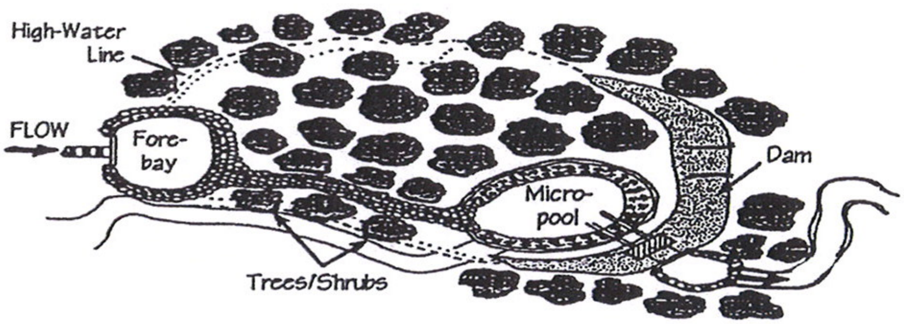
ACTIVITY: Dry Detention Ponds — WPTP-02



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
● Sediment	● Heavy Metals	◗ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Implementation Requirements			
● High	◗ Medium		○ Low
◗ Capital Costs	◗ O & M Costs	◗ Maintenance	○ Training

Description

Extended detention ponds are dry between storms. During a storm the pond fills. A bottom outlet releases the stormwater slowly to provide time for sediments to settle. This management practice is likely to provide a significant reduction in sediments and heavy metals as well as a partial reduction in nutrients, toxic materials, floatable materials, oxygen demanding substances, and oil and grease.

Selection Criteria

- Objective is to remove only particulate pollutants (soluble pollutants are not intended to be removed).
- Use where lack of water prevents the use of wet ponds, wetlands or biofilters.
- Use where shallow wet ponds or wetlands would cause unacceptable mosquito conditions.
- Multiple benefits for passive recreation during dry periods (multi-purpose facilities, ball fields, picnicking etc.).
- The quality of the runoff and the intent of the basin should be considered. If the basin is being considered for highly soluble pollutant removal such as nutrients, then a wet detention pond is preferred over a dry detention pond.
- Dry detention ponds and vaults may be particularly appropriate to areas where dry weather base flow cannot be used to maintain water levels, as is required for wet ponds and constructed wetlands. These systems are suitable for essentially any size tributary area from an individual commercial development to a large residential area. Surface ponds are less expensive to construct, but underground vaults may be appropriate in commercial developments. Use of concrete retaining walls will reduce the space required by a pond. The basic elements of a dry detention basin are illustrated in Figures WPTP-02-1 and 2. Additional details are

provided in Figures WPTP-02-3 through 9.

- Dry ponds provide lower removal efficiency for dissolved pollutant parameters than wet ponds and constructed wetlands.

Design and Sizing Considerations

- These systems should be designed by a licensed professional civil engineer.
- Dry detention ponds should be designed as "off-line" structures to limit environmental impacts downstream when maintaining the facility. On-line facilities may be acceptable depending on specific site characteristics.
- Pond volume is sized to capture 85-95% of theoretical annual volume of the runoff. Generally, the pond is sized to capture and "treat" at least the "first flush" volume.
- Drawdown time of 24 to 48 hours.
- A shallow pond with large surface area performs better than a deep pond with the same volume. Design to minimize short-circuiting by including energy dissipaters on inlets, shape the pond with at least a 3:1 length to width ratio, and locate the inlets as far away from the outlet as possible. It should be noted that a length to width ratio of up to 7:1 is preferred. The inlet and outlet can be placed at the same end if baffling is installed to direct the water to the opposite end before returning to the outlet. If topography or aesthetics requires the pond to have an irregular shape, the pond area and volume should be increased to compensate for the dead spaces.
- Place energy dissipators at the entrance to minimize bottom erosion and resuspension.
- Vegetate side slopes and bottom to the maximum extent practical.
- If side erosion is particularly severe, consider soil stabilization, armoring or lastly paving.
- If floatables are a problem, protect outlet with trash rack, skimmer at inlet, or other device.
- Do not locate on fill sites or on or near steep slopes if it is expected that much of the water will exit through the bottom, or modify the bottom to prevent excessive infiltration.
- Embankment freeboard of at least 2 feet (0.61 m).
- Side slopes of at least 4:1 (H:V) unless vertical retaining walls are used.
- Provide dedicated access to the basin bottom (minimum 4:1 (H:V)) for maintenance vehicles.
- With a riser structure, include an anti-vortex device and a debris barrier.

- Skimmers – Facilities that receive stormwater from contributing areas with greater than 50 percent impervious surface or that are a potential source of oil and grease contamination must include a baffle, skimmer, and grease trap to prevent these substances from being discharged from the facility.

- Bedrock must be considered in the Williamson County area because excavation may be required for grading. The "live" pool may be excavated into bedrock for a dry detention pond, but the cost may be prohibitive. Furthermore, if there is highly fractured bedrock or karst topography, then the modification of a detention pond should be carefully considered because it may not hold water and the additional water flow and/or weight could intensify karst activity.

- The interaction with other utilities must be considered. The cost of designing around utilities or utility relocation must be considered.

- Access must be considered to account for maintenance crews and public interaction. Maintenance crews must have access to the site for proper maintenance. Ponds that are not designed with access for maintenance crews often become more of a nuisance than a beneficial part of a stormwater management program. It may also be desirable to encourage or discourage access for the public. Public education and recreation may be facilitated by access to the pond, provided public safety is sufficiently addresses. In some cases, however, it may be desirable to restrict public access such as in especially sensitive or dangerous areas.

- Include a forebay to facilitate maintenance.

- With earthen walls, place an antiseep collar (or collars) around the outlet pipe.

- The outlet should incorporate an antivortex device if the facility is large (A 100-year storm must safely pass through or around the device).

- The sides of an earthen wall should be vegetated to avoid erosion. Drought tolerant groundcover species should be used if irrigation can not occur during the summer.

- The public's safety must be a foremost consideration. For the design of dry detention ponds, this usually takes place in the grading, fencing, landscaping, pipe cover, grating and signage. The most important design feature affecting public safety during a pond's operation is grading. The contours of the pond should be designed to eliminate "drop-offs". In some cases there is not sufficient room for grading of this type and the pond may require a perimeter fence.

<u>Pond Sizing</u>

- Water quality requirements for detention ponds should be sized to collect the first flush of stormwater runoff; and release it over a 24- to 48-hour period. For this region, the first flush is generally the first 0.5 to 1.0 inches of runoff depending on the density and percent imperviousness of the land use.

<u>Sizing the "Live" Pool</u>

The following method should be used to calculate the "live" pool volume.

- The recommended performance goal is 85 to 95%. The live pool may be calculated using long-term hourly hydrologic data and runoff capture simulation curves that consider a runoff coefficient for land use to determine a unit basin storage volume (v). This has been analyzed for the middle Tennessee area and is presented in Figure WPTP-02-3.

$$V_L = (A_T * v)/12$$

where: V_L = pond volume (acre-feet);
A_T = Total Tributary Area (acres); and
v = unit basin storage volume (inches) taken from Figure WPTP-02-3

- The live pool volume will benefit the downstream waterways by reducing erosive velocities, providing stormwater quality benefit, and some flood control.

- To achieve an equivalent pollutant capture percentage as a wet pond, 85 to 95 percent of the runoff must be captured and detained. Capture volumes over 95 percent are generally not cost effective as demonstrated by the "knee" of the curve presented in Figure WPTP-02-3. Therefore it is recommended that an average capture volume of 90 percent be used for determining the detention basin size required. Because of the possibility of resuspension of materials during extreme storms, consideration should be given to placing the basin off-line. That is, it should have a bypass for the extreme events. Bypassing larger events will also allow the bedload earned by the storm and is necessary for beach replenishment to move downstream.

- A drawdown time of 24 to 48 hours is recommended in order to settle out the finer clay particles as stated above; however, 24 hours can be used if it can be demonstrated that this rate will remove 90% of the solids.

- About 10 to 25% of the surface area determined in the above procedure should be devoted to the forebay. The forebay can be distinguished from the remainder of the pond by one of several means: a lateral sill with rooted wetland vegetation, two ponds in series, differential pool depth, rock-filled gabions or retaining wall, or a horizontal rock filter placed laterally across the pond.

<u>Outlet Design</u>

- Proper hydraulic design of the outlet is critical to achieving good performance of the detention basin. The two most common outlet problems that occur are: 1) the capacity of the outlet is too great resulting in partial filling of the basin and less than designed for drawdown time and 2) the outlet clogs because it is not adequately protected against trash and debris. To avoid these problems, two alternative outlet types are recommended for use: 1) V-notch weir, and 2) perforated riser.

- Three different approaches can be used to control the outflow. One is to use a "V" notch weir. One is to use a single orifice outlet with or without the protection of a riser pipe. Lastly, a perforated riser itself may be used for discharge control. These approaches are presented below.

Flow Control Using a "V" Notch Weir

The outlet control "V" notch weir should be sized using the following formula (Merritt et.al., 1996).

$$Q = C_1 H^{5/2} \tan\left(\frac{\theta}{2}\right)$$

Where

θ = notch angle
H = head or depth of water over weir, ft
C_1 = discharge coefficient (see Figure WPTP-02-9)

The notch angle should be 20° or more. If calculations show that a notch angle of less than 20° is appropriate, then the outlet should be designed as a uniform width notch. This will generally necessitate some sort of floatables control such as a skimmer on the outlet or trash rack on the inlet.

Flow Control Using a Single Orifice

The outlet control orifice should be sized using the following equation (GKY, 1989).

$$a = \frac{2A(H-H_o)^{0.5}}{3600CT(2g)^{0.5}} = \frac{(7x10^{-5})A(H-H_o)^{0.5}}{cT}$$

where:
a = area of orifice (ft^2)
A = average surface area of the pond (ft^2)
c = orifice coefficient
T = drawdown time of full pond (hrs.)
g = gravity (32.2 ft/sec^2)
H = elevation when the pond is full (ft)
H_o = final elevation when pond is empty (ft)

With a drawdown time of 40 hours the equation becomes:

$$a = \frac{(1.75x10^{-6})A(H-H_o)^{0.5}}{c}$$

Care must be taken in the selection of "c": 0.60 is most often recommended and used. However, based on actual tests GKY (1989) recommends the following:

c = 0.66 for thin materials, that is, the thickness is equal to or less than orifice diameter
c = 0.80 when the material is thicker than the orifice diameter

Drilling the orifice into an outlet structure that is made of concrete can result in considerable impact on the coefficient, as does the beveling of the edge. The experiments by GKY (1989) were with sharp edged orifices.

- Additional steps may be necessary to be certain that the small storms, which represent the majority of pollution, are effectively treated. One approach would be to check the design analysis to determine if the facility takes 24-48 hours to drain when half full. If not, either modify the design to achieve this objective, or install a two orifice outlet. The lower outlet is sized to drain a half-full facility in 24 hours. The second orifice is placed at the mid-water elevation and is sized in combination with the lower orifice to drain the entire facility in 48 hours. Another approach is to install the outlet about one foot above the bottom of the pond (essentially enlarging the micropool area). This lower area will dry up between storms and will capture much of the volume of small storms and improving pollutant removal.

- To prevent clogging of an orifice and the bottom orifices of the riser pipe, wrap the bottom three rows of orifices with geotextile fabric and a cone of one to three inch rock. The holes in the riser pipe should not be modified to achieve a 48-hour drawdown time.

TABLE 3A PERFORATED OUTLET RISER PIPE ORIFICES (Austin, 1988)

RISER PIPE DIAMETER	VERTICAL SPACING BETWEEN ROWS (center to center)	NUMBER OF PERFORATIONS	PERFORATION DIAMETER
6 in. (15.2 cm)	2.5 in. (6.4 cm)	9 per row	1 in. (2.54 cm)
8 in. (20.3 cm)	2.5 in. (6.4 cm)	12	1 in. (2.54 cm)
10 in. (25.4 cm)	2.5 in. (6.4 cm)	16	1 in. (2.54 cm)

<u>Flow Control Using the Perforated Riser</u>
For outlet control using the perforated riser, it is recommended to use the procedure illustrated in Figures WPTP-02-5, 6 and 7. This design incorporates flow control for the small storms in the perforated riser but also provides an overflow outlet for large storms. If properly designed, the facility can be used for both water quality, flood, and erosion control by: 1) sizing the perforated riser as indicated for water quality control; 2) sizing the outlet pipe to control peak outflow rate from the 2-year storm; and 3) using a spillway in the pond berm to control the discharge from larger storms up to the 100-year storm.

Construction/ Inspection Considerations

- Make sure the outlet is installed as designed. Special attention should be given to the elevations of each outlet geometry change, shape of the various weirs or orifices, and installation of cut-off collars in embankments.

Maintenance

- Check outlet regularly for clogging and remove any debris.
- Check banks and bottom of surface basin for erosion and correct as necessary.
- Remove sediment when accumulation reaches 6 inches, or if resuspension is observed or probable. Sediment may be permitted to accumulate deeper than 6

inches if there is a permanent marker indicating the depth where sediment needs to be removed, and that mark has not been met.

Sediment Removal

- A primary function of ponds are to collect sediments. The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The sediment contents should be identified before it is removed and disposed.

  Some sediment may contain contaminants of which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then TDEC should be consulted and their disposal recommendations followed. The TDEC – Division of Water Pollution Control should be contacted at (615) 532-0625. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than "clean" soil) are suspected to accumulate and be conveyed via storm runoff.

  Some sediment collected may be innocuous (free of pollutants other than "clean" soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff. The sediment should not be placed within the high water level area of the ponds, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

- Check at least annually and after each extreme storm event. The facility should be cleaned of accumulated debris. The banks of surface ponds should be checked and areas of erosion repaired. Remove nuisance wetland species and take appropriate measures to control mosquitoes. Remove sediments if they are within 18 inches of an orifice plate.

- The pond's success as a mechanism to benefit water quality is dependent on maintaining the permanent pool, skimmer devices, and inlet and outlet structures. This maintenance typically includes sediment, floatable, and debris removal from inlets, outlets and skimmers.

- Pond vegetation need to be trimmed or harvested as appropriate, grassy areas frequently mowed and repairs made to signage, walkways, picnic tables, or any other public recreation equipment.

- If both the operational aesthetic characteristics of a dry pond are not maintained, then it will be viewed as an eyesore and negative environmental impact even if it is functioning properly.

Cost Considerations

- Generally less expensive than wet ponds and wetlands, but more expensive than biofilters.

Limitations

- Require more frequent maintenance then wet ponds.
- Inability to vegetate banks and bottom may result in erosion and pollutant resuspension.
- Limitation of the orifice diameter may preclude use in small watersheds.
- Pending their volume and depth basin designs may require approval from State Division of Safety of Dams. Generally, any embankment 15 feet (4.6 m) or taller must meet special requirements. For larger detention facilities, the structural integrity of the impounding embankment should also be considered. The embankment should be protected against catastrophic dam failure. Pending volume and depth, pond designs may require approval from TVA, TDEC, or USACOE for various reasons including dam safety.
- Dry detention ponds require a large surface area (0.5 to 3% of the contributing drainage area) to provide sufficient pond volume for settling of sediment.
- If upstream erosion is not properly controlled, dry detention ponds can be maintenance intensive with respect to sediment removal, nuisance odors, and insects (i.e., mosquitoes), etc.
- Dry detention ponds require a differential elevation between inlets and outlets and thus, may be limited by terrain.
- May require permits from various regulatory agencies, e.g., TVA, TDEC, USACOE.

Additional Information

- A "V" notch weir outlet structure as illustrated in Figure WPTP-02-2 is preferred.

Primary References

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Camp Dresser & McKee, *Sevenmile Creek Basin Pilot Stormwater Quality Master Plan*, Report to Metropolitan Nashville and Davidson County, Tennessee, December 1999.

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Roesner, L. A., Aldrich, J., Hartigan, J.P., et.al., *Urban Runoff Quality Management – WEF Manual of Practice No. 23 / ASCE Manual and Report on Engineering Practice*

No. 87, 1998.

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Metropolitan Washington Council of Governments (MWCOG), 1983, *"Nationwide Urban Runoff Program Pollution Removal Capability of Urban Best Management Practices in the Washington Metropolitan Area"*, available from NTIS, PB84-245497.

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Urban Drainage & Flood Control District, Denver Colorado, *"Urban Storm Drainage Criteria Manual - Volume 3 – Best Management Practices - Stormwater Quality"*, September, 1992.

Whipple, W. and J. Hunter, 1981, *"Settleability of Urban Runoff Pollution"*, J. Water Pollution Control Federation, 53 (12): 1726-1731.

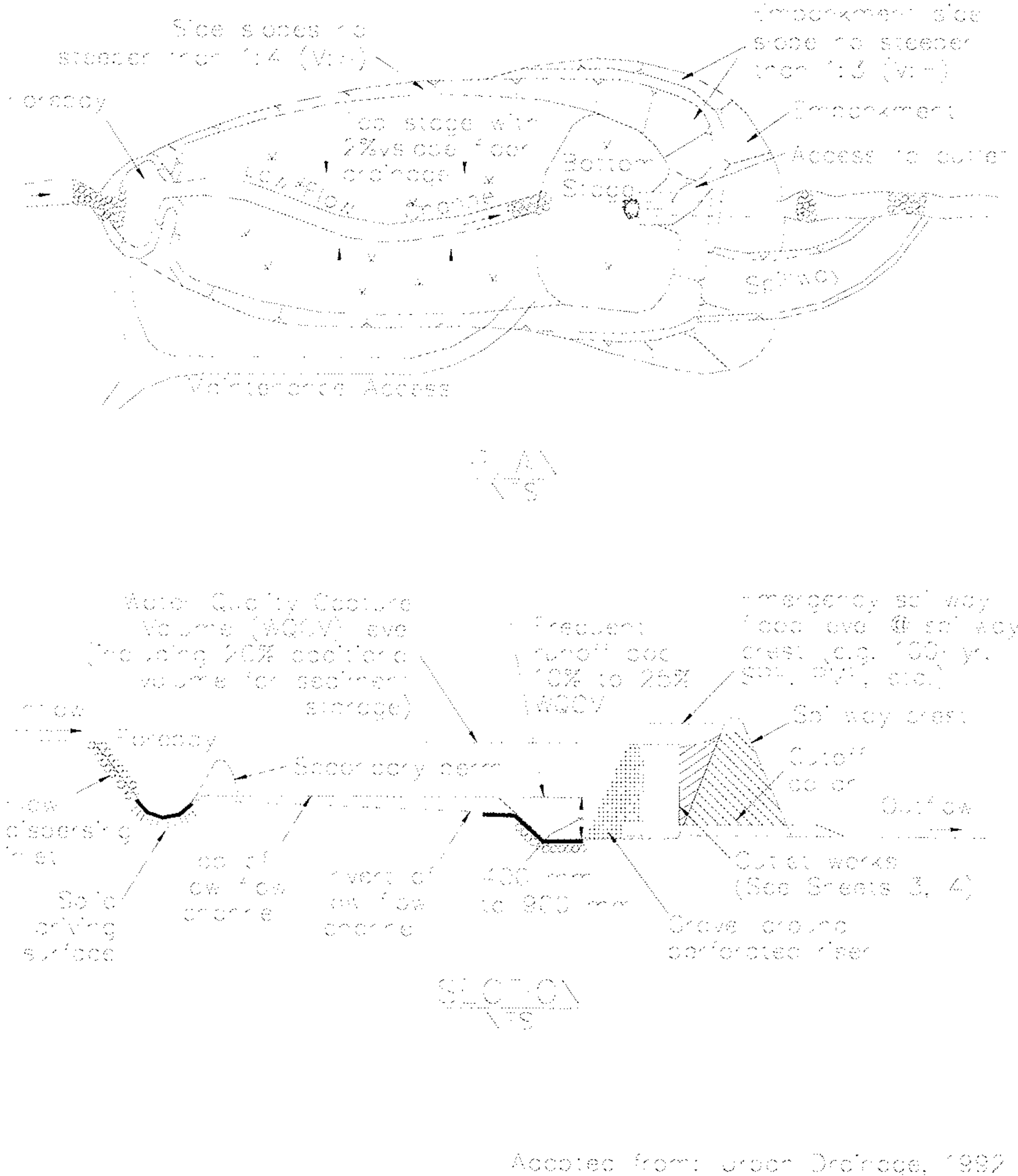


Figure WPTP-02-1
Dry Detention Pond Layout

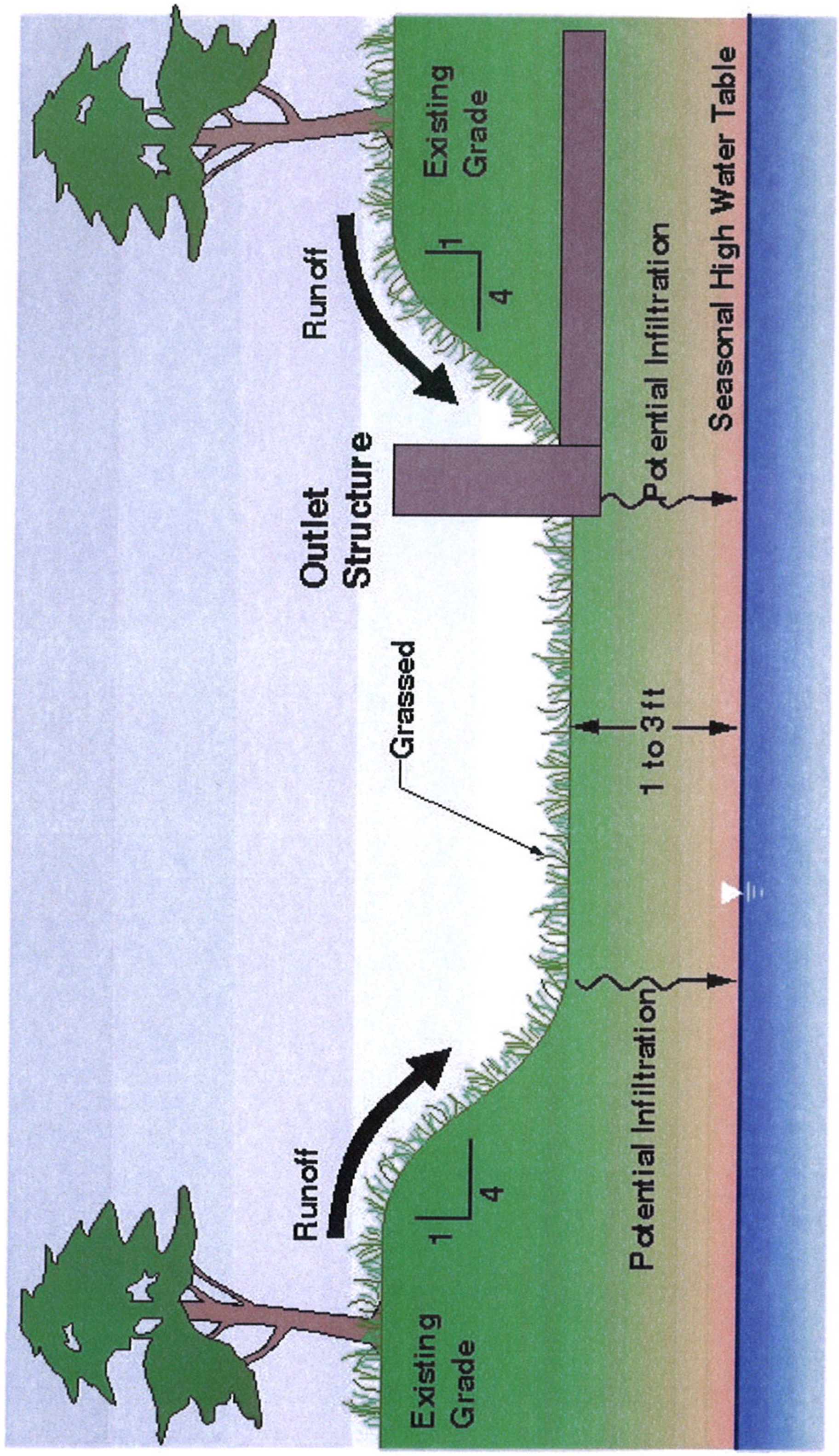


Figure WPTP-02-2
Dry Detention Pond Layout

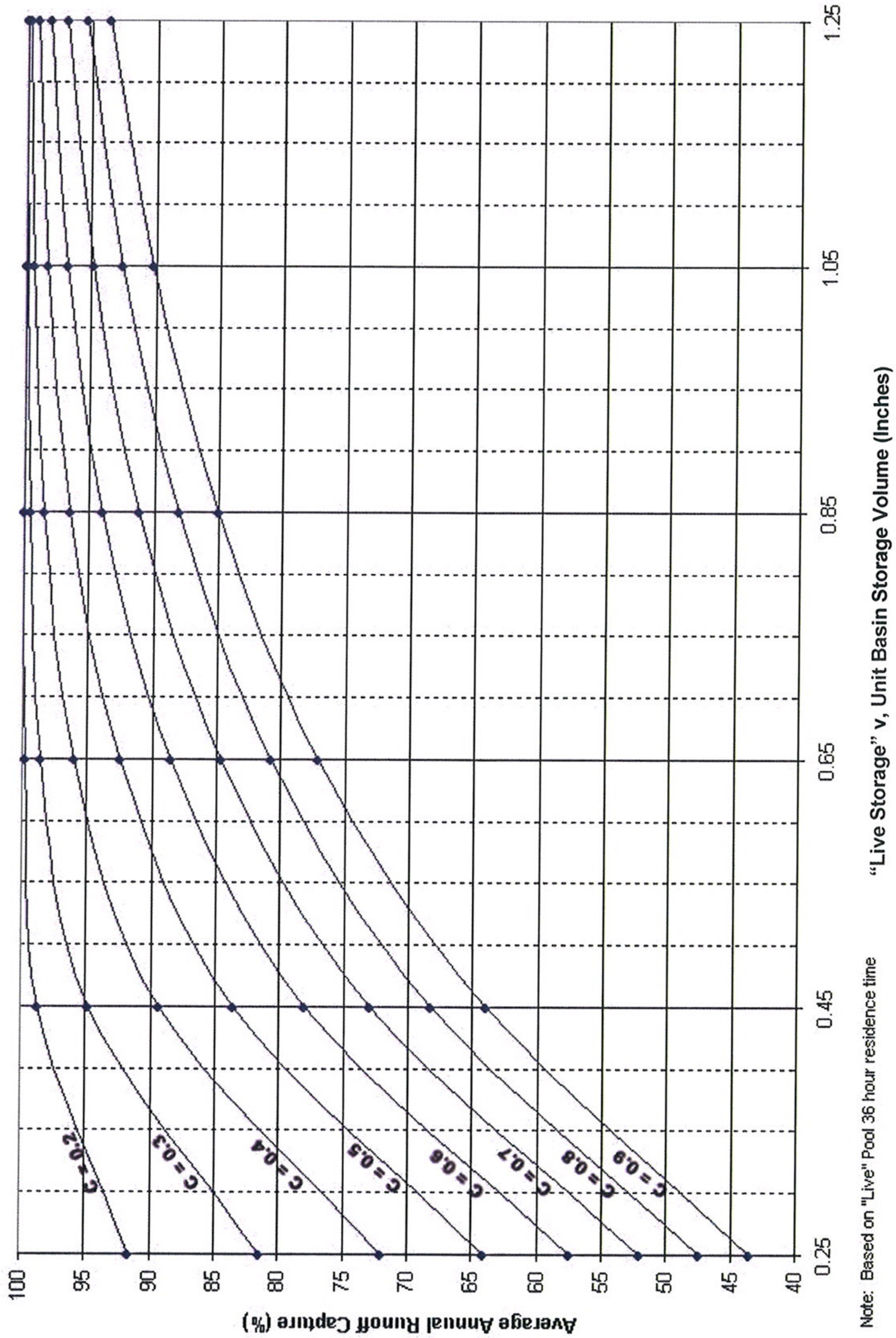
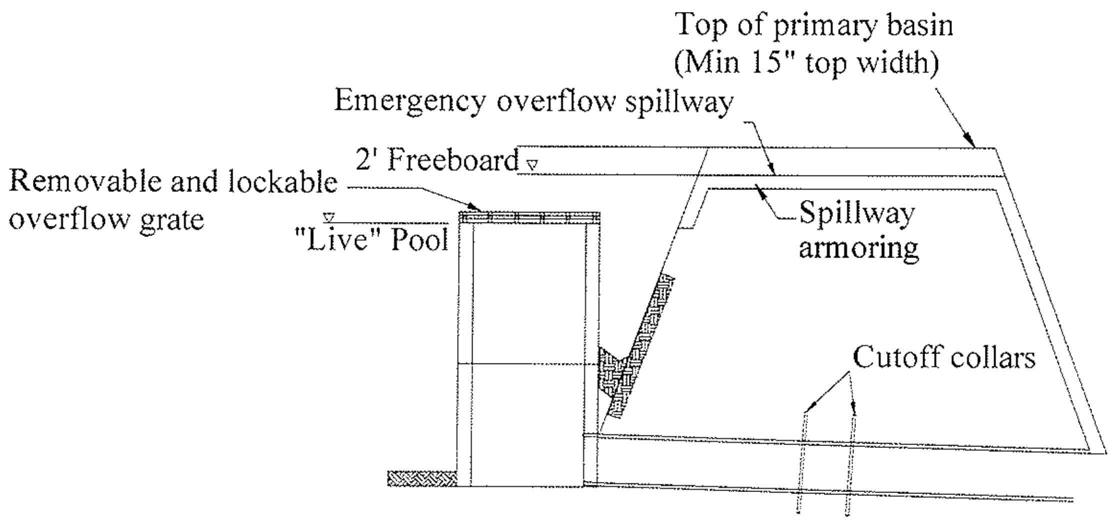
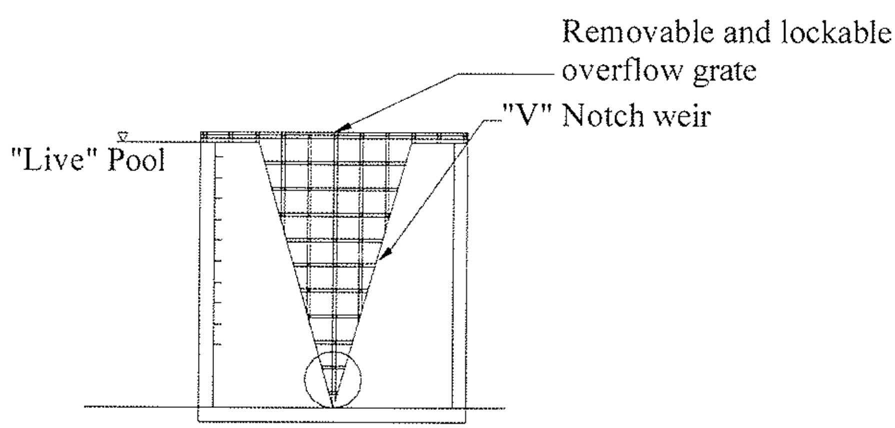


Figure WPTP-02-3
Dry Detention Average Annual Runoff Volume Capture



SECTION OUTLET STRUCTURE

NTS



PROFILE OUTLET STRUCTURE

NTS

Figure WPTP-02-4
"V" Notch Weir Outlet Structure

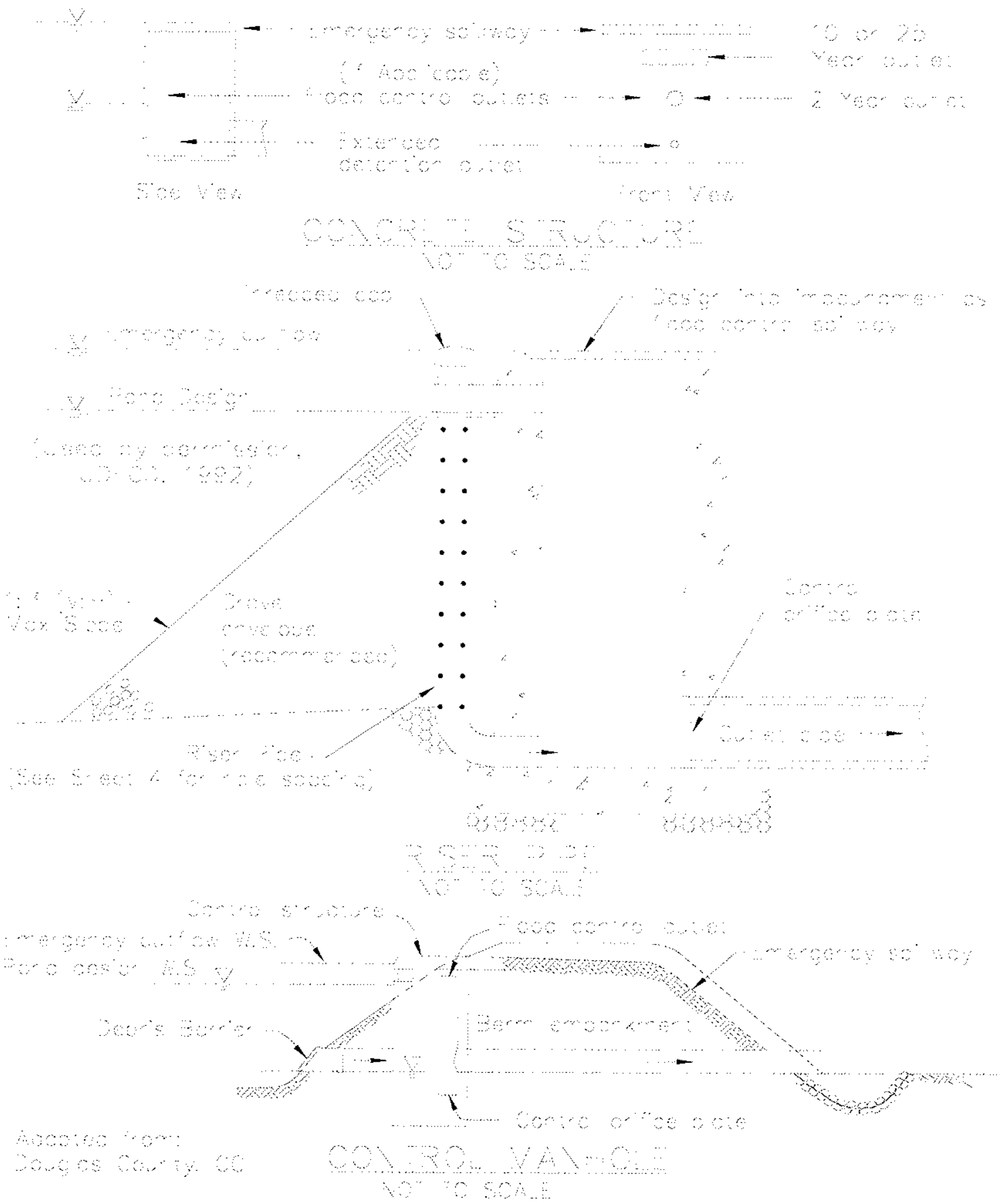
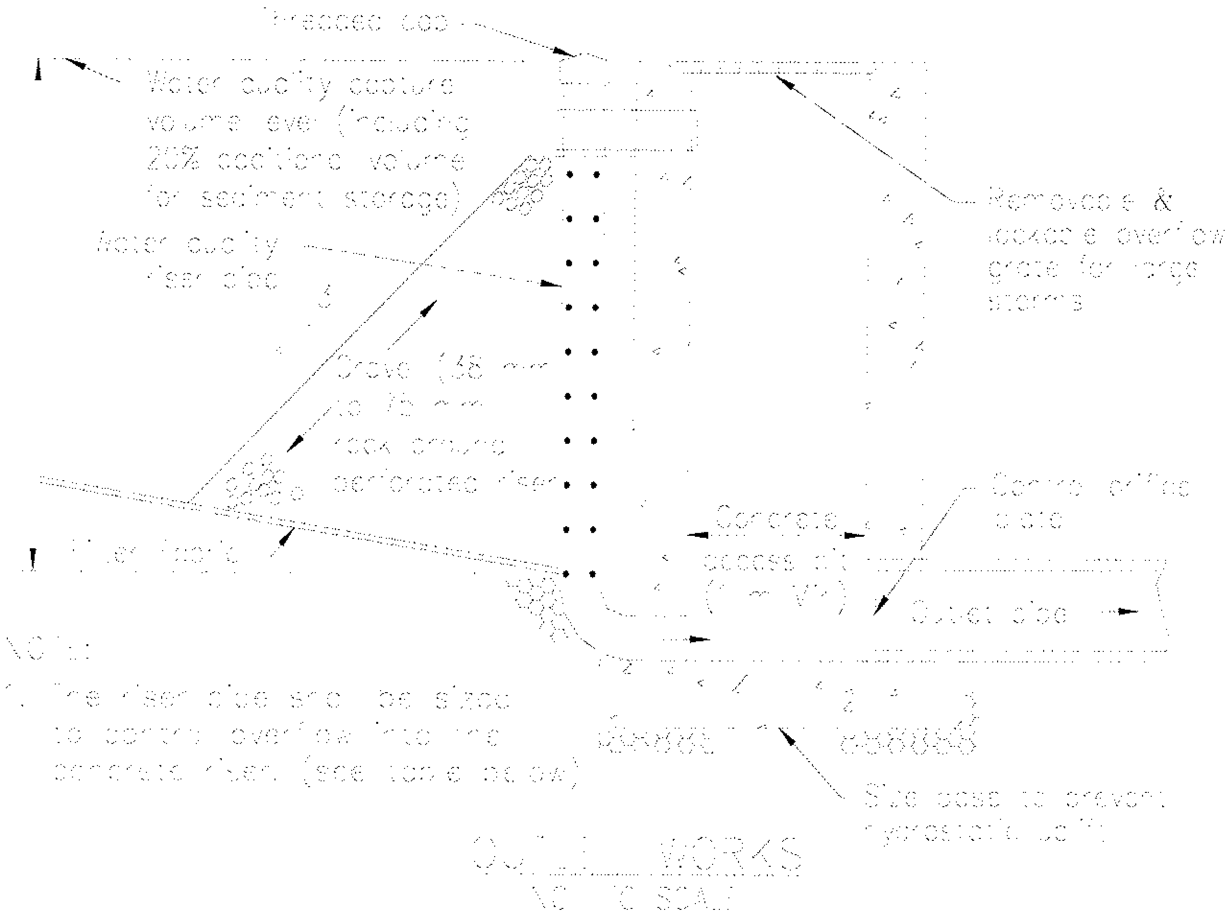


Figure WPTP-02-5
Other Outlet Structures



Perforated Outlet Riser Pipe Orifices (Austin, 1988)

Riser Pipe Diameter	Vertical Spacing Between Rows (center to center)	Number of Perforations	Perforation Diameter
150 mm	64 mm	9 per row	25 mm
200 mm	64 mm	12 per row	25 mm
250 mm	64 mm	16 per row	25 mm

Figure WPTP-02-6
Riser Pipe Sizing

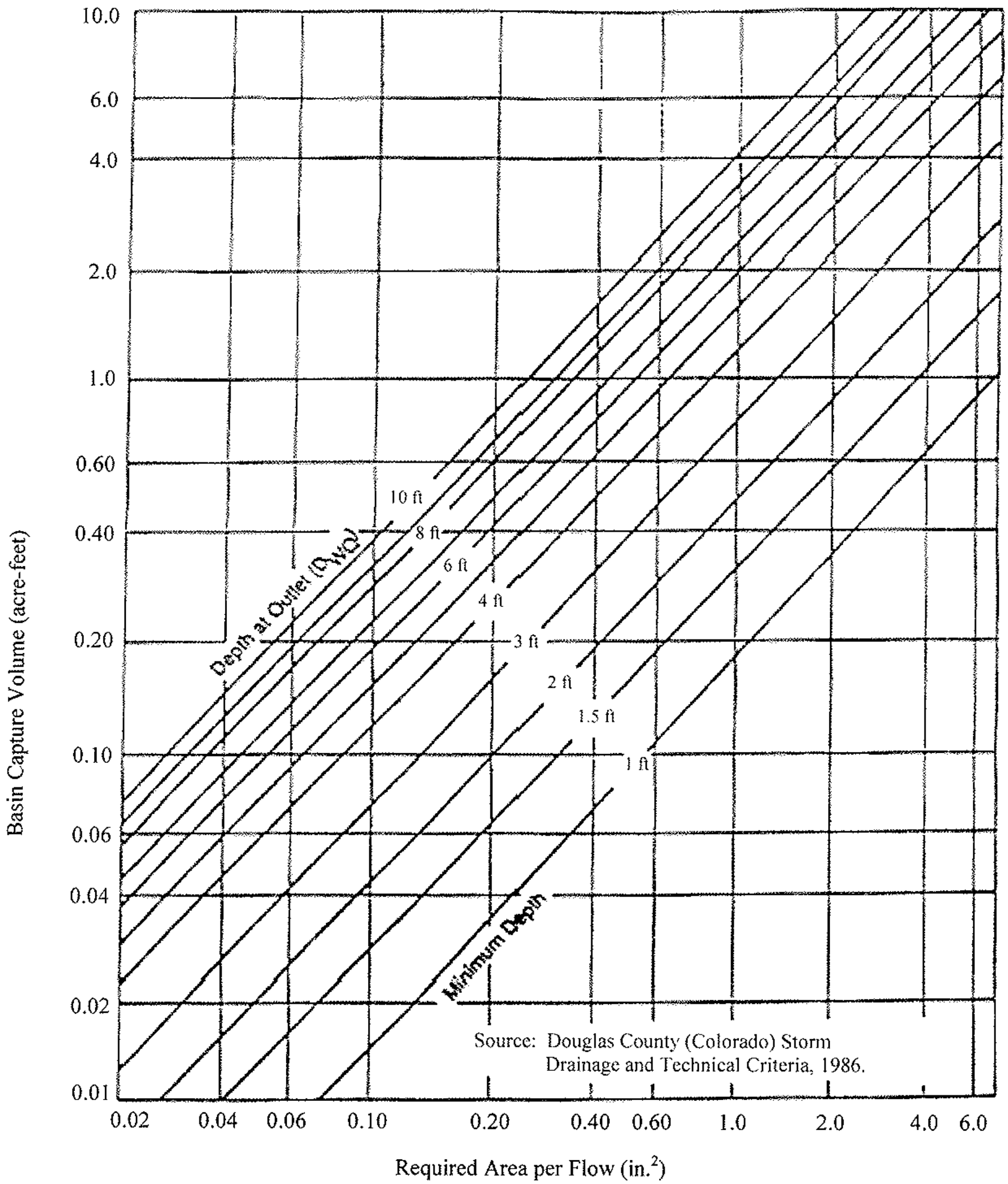


Figure WPTP-02-7
Perforated Riser Pipe Sizing
(Dry Detention Pond with 40-hour Drain Time of Capture Volume)

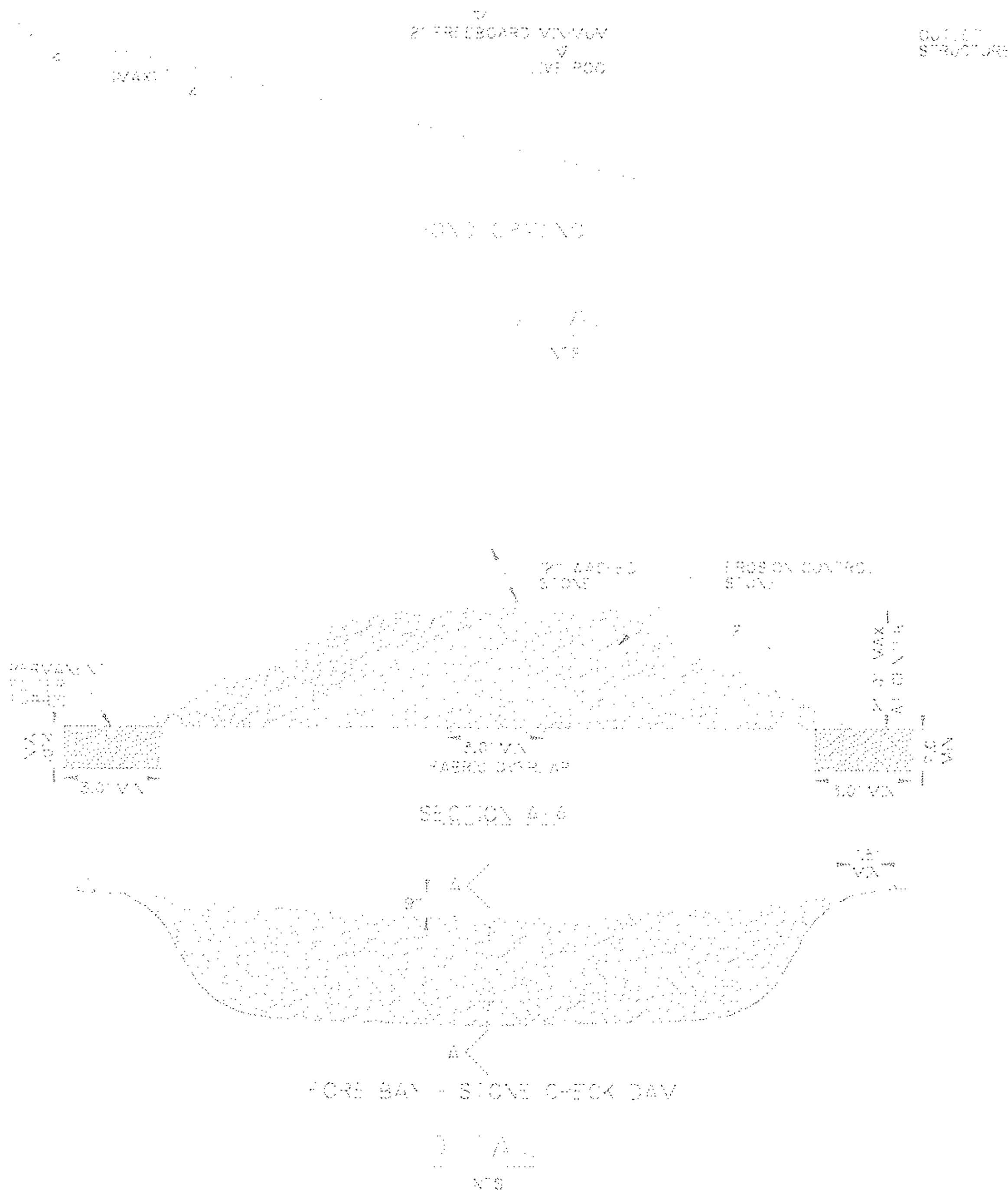


Figure WPTP-02-8
Dry Detention Pond Layout Details

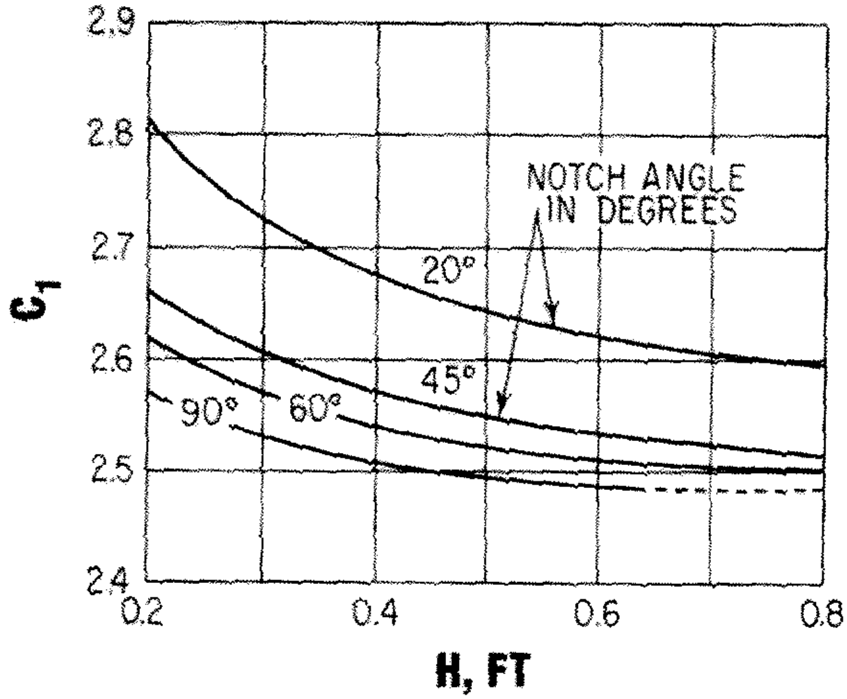


Figure WPTP-02-9
Sharp-Crested "V" Notch Weir Discharge Coefficients